Method and apparatus for controlling a virtual reality graphics system using interactions

5   Description

The present invention generally relates to graphics
systems for virtual reality (VR) applications and
specifically relates to a method and an apparatus for
10   controlling such a VR graphics system using
interactions as claimed in the preambles of the
respective independent claims.

A VR graphics system which is concerned in this case is
15   evident from DE 101 25 075 A1, for example, and is used
to generate and display a multiplicity of three-
dimensional views which together represent a virtual
three-dimensional scene. In this case, such a scene is
usually correspondingly visualized using stereoscopic
20   projection onto a screen or the like. So-called
immersive VR systems which form an intuitive man-
machine (user) interface for the various areas of use
(fig. 1) are already relatively widespread. Said
graphics systems use a computer system to highly
25   integrate the user into the visual simulation. This
submersion of the user is referred to as "immersion" or
an "immersive environment".

As a result of the fact that three-dimensional data or
30   objects are displayed to scale and as a result of the
likewise three-dimensional ability to interact, these
data or objects can be assessed and experienced far
better than is possible with standard visualization and
interaction techniques, for example with a 2D monitor
35   and a correspondingly two-dimensional graphical user
interface. A large number of physical real models and
prototypes may thus be replaced with virtual prototypes
in product development. A similar situation applies to
planning tasks in the field of architecture, for

example. Function prototypes may also be evaluated in a
considerably more realistic manner in immersive
environments than is possible with the standard
methods.

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Such a VR simulation is controlled in a computer-aided
manner using suitable input units (referred to below,
for the purpose of generalization, as "interaction
units" since their function goes beyond pure data

10 input) which, in addition to pushbuttons, have a
position sensor which can be used to likewise
continuously measure the spatial position and
orientation of the interaction unit in order to carry
out the interactions with the data which are displayed

15 in the form of a scene (scene data). Such an
interaction unit and a corresponding three-dimensional
user interface are disclosed, for example, in DE 101 32
243 A1. The handheld cableless interaction unit
described there is used to generate and transmit

20 location, position and/or movement data (i.e. spatial
position coordinates of the interaction unit) for the
purpose of three-dimensional virtual navigation in said
scene and in any functional elements of the user
interface and for the purpose of manipulating virtual

25 objects in the scene. To this end, the interaction unit
has a sensor which interacts, via a radio connection,
with a position detection sensor system provided in the
VR graphics system. Said position data comprise the six
possible degrees of freedom of translation and rotation

30 of the interaction unit and are evaluated in real time
in a computer-aided manner in order to determine a
movement or spatial trajectory of the interaction unit.

User-guided interactions may, in principle, be

35 subdivided into a logical part and a physical part. The
logical part is the virtual three-dimensional user
interface and includes, for example, the display of
functions or menus, the method of selecting objects or

function modes and the type of navigation. The physical part corresponds to the equipment-related implementation such as the technical configuration of the interaction unit and the projection technology used
5   to display the scene.

As regards the use of said interaction units, it is desirable for said interactions, in particular more complex interactions such as function selection or menu
10   control, to be as technically simple as possible and nevertheless to be capable of being controlled in a manner which is as safe as possible to use and is as operationally reliable as possible.

15   The invention therefore proposes a method and an apparatus for controlling a virtual reality (VR) graphics system (which is concerned in this case) using said interactions, which method and apparatus are based on the inventive concept of first of all forming a
20   reference system, which is arranged on the spatial or movement trajectory of the interaction unit, and evaluating subsequent interactions using this reference system.

25   The special feature of the inventive method therefore resides in the fact that, as a result of a first interaction by the user, an initial spatial point which is initially fixed is determined, preferably together with an associated reference coordinate system, on the
30   spatial trajectory of the interaction unit, and that the interaction unit is used to evaluate at least one subsequent interaction relative to the initial spatial point determined and the associated reference coordinate system.
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Another refinement provides for the initial spatial point to represent the zero point or origin of said reference coordinate system and for reference or

threshold values to be prescribed in this coordinate
system, a particular function or a particular menu
selection associated with the virtual user interface,
which has been inserted into the current scene, being
5   effected when said reference or threshold values are
exceeded by the instantaneous spatial position or
spatial orientation of the interaction unit. These
reference values are preferably located on the surface
of a geometric body which is arranged symmetrically
10   (imaginary) with respect to the initial spatial point,
for example on the surface of a sphere, the surface of
an ellipsoid, the surface of a cube, the surface of a
cuboid, the surface of a tetrahedron or the like. The
reference points may also be weighted in particular
15   spatial directions in order to assign different
sensitivities to particular functions or menu selection
items, during three-dimensional interaction, along the
real spatial trajectory of the interaction unit, as a
result of which incorrect operation or incorrect inputs
20   by a user are avoided even more effectively.

Another refinement provides at least one further
threshold value whose magnitude is greater than said at
least one reference value, the reference coordinate
25   system and the initial spatial point being caused to
move to the new spatial position when said further
threshold value is exceeded by the instantaneous
spatial position of the interaction unit. This has the
advantage that said advantageous method of operation of
30   the reference coordinate system during said function or
menu selection remains even in the case of
(inadvertently) excessive changes in the position of
the interaction unit.

35   The procedure proposed according to the invention and
the user interface which is likewise proposed afford
the advantage, in particular, that even complex
interactions, for example over a plurality of function

or menu levels, can be effected very intuitively, to be
precise solely by means of spatial movement of the
interaction unit. Only the determination of the first
initial spatial point must be effected by means of a

5   special interaction, preferably by means of a control
element which is arranged on the interaction unit, for
example a pushbutton or the like. In addition, control
of the user interface by continuously evaluating said
trajectory of the interaction unit becomes easier to

10   handle   and   even   more   operationally   reliable   in
comparison with the interaction systems which are known
in the prior art.

Control of the VR graphics system using the interaction

15   unit and a user interface that is visually inserted
into the respective scene is preferably effected either
via a function selection that is displayed in a three-
dimensional visual manner or via a menu system such as
the spherical menu described, for example, in DE 101 32

20   243 A1.

The invention can be used, with said advantages, in
cableless and cable-bound interaction units which are
preferably hand-guided by the user. It should be

25   emphasized   that,   in   addition   to   said   use   of   the
interaction   unit   including   said   control   element
(pushbutton), the possible interactions may also take
place by means of acoustic or optical interactions, for
example by means of voice, gestures or the like. In

30   this   case,   use   may   be   made   of   the   input   methods
described in detail in the dissertation by A. Rößler
entitled "Ein System für die Entwicklung von räumlichen
Benutzungsschnittstellen"   [A   system   for   developing
three-dimensional   user   interfaces],   University   of

35   Stuttgart, published by Jost Jetter Verlag, Heimsheim,
particularly   on   pages   72   ff.   (chapters   4.3.2   ff.)
thereof. In addition to the use of said interaction
unit, the interaction modes described there such as

direct and indirect and absolute and relative input may
thus be additionally used to enable, for example,
event-oriented interpretation of movements of the
interaction unit or a part of the user's body.

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In the case of said interpretation of the user's
gestures, it is also possible to distinguish between
static and dynamic gestures, the temporal sequence of a
movement being analyzed in the case of dynamic gestures
10 and a relative position or orientation between
individual parts of the user's body, for example, being
analyzed in the case of static gestures. In addition,
it is possible to distinguish between simple input
events and interpreted and combined input events,
15 simple input events being triggered by discrete actions
by the user, for example the operation of said
pushbutton, whereas interpreted events are dynamically
interpreted, for example taking into consideration a
time measurement, for example when a button is pressed
20 twice ("double click"). These two input modes may
finally be combined in any desired manner, for example
pressing a button once with a hand, head or facial
gesture.

25 The inventive method and the apparatus are described
below with reference to exemplary embodiments which are
illustrated in the drawing and which reveal further
features and advantages of the invention. In said
exemplary embodiments, identical or functionally
30 identical features are referenced using corresponding
reference symbols.

In the drawing:

35 fig. 1   shows a simplified overview of an
                     immersive VR (virtual reality) graphics
                     system which is concerned in this case;

figs. 2a-c   show spatial trajectories, which
                  typically result when an interaction
                  unit as shown in fig. 1 is physically
                  moved in a three-dimensional manner, in
5   order to illustrate the inventive
                  procedure when evaluating these
                  trajectories; and

fig. 3   uses a flowchart to show the
10   illustration of an inventive routine for
                  controlling an interaction unit which is
                  concerned in this case.

The VR graphics system which is diagrammatically
15 illustrated in fig. 1 has a projection screen 100 in
front of which a person (user) 105 stands in order to
view the scene 115, which is generated there via a
projector 110, using stereoscopic glasses 120. It goes
without saying that auto-stereoscopic screens or the
20 like may also be used in the present case instead of
the stereoscopic glasses 120. In addition, the
projection screen 100, the projector 110 and the
glasses 120 may be replaced in the present case with a
data helmet which is known per se and then comprises
25 all three functions.

The user 105 holds an interaction unit 125 in his hand
in order to generate preferably absolute position data
such as the spatial position and orientation of the
30 interaction unit in the physical space and to transmit
said data to a position detection sensor system 130 -
140. Alternatively, however, relative or differential
position data may also be used but this is not
important in the present context.

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The interaction unit 125 comprises a position detection
system 145, preferably an arrangement of optical
measurement systems 145, both the absolute values of

the three possible angles of rotation and the absolute
values of the translational movements of the
interaction unit 125, which are possible in the three
possible spatial directions, being detected using said
5   arrangement of measurement systems and being processed
in real time by a digital computer 150 in the manner
described below. Alternatively, these position data may
be detected using acceleration sensors, gyroscopes or
the like which then generally provide only relative or
10 differential position data. Since this sensor system is
not important in the present case, a more detailed
description is dispensed with here and reference is
made to the documents mentioned at the outset.

15 Said absolute position data are generated by a computer
system which is connected to the interaction unit 125.
To this end, they are transmitted to a microprocessor
160 of a digital computer 150 in which, inter alia, the
necessary graphical evaluation processes (which are to
20 be assumed to be familiar to a person skilled in the
art) are carried out in order to generate the
stereoscopic three-dimensional scene 115. The three-
dimensional scene representation 115 is used, in
particular, for visualizing object manipulations, for
25 three-dimensional navigation in the entire scene and
for displaying function selection structures and/or
menu structures.

In the present exemplary embodiment, the interaction
30 unit 125 is connected, for carrying data, to the
digital computer 150, via a radio connection 170, using
a reception part 165 (which is arranged there). The
position data which are transmitted from the sensors
145 to the position detection sensor system 130 - 140
35 are likewise transmitted in a wireless manner by radio
links 175 - 185.

Additionally depicted are the head position (HP) of the
user 105 and his viewing direction (VD) 190 with
respect to the projection screen 100 and the scene 115
projected there. These two variables are important for
5   calculating a current stereoscopic projection insofar
as they considerably concomitantly determine the
necessary scene perspective since the perspective also
depends, in a manner known per se, on these two
variables.
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In the present exemplary embodiment, the interaction
unit 125 comprises a pushbutton 195 which the user 105
can use, in addition to said possibilities for moving
the interaction unit 125 in the space, to mechanically
15 trigger an interaction, as described below with
reference to fig. 3. It goes without saying that two or
more pushbuttons may also alternatively be arranged in
order to enable different interactions, if appropriate.

20 The central element of the immersive VR graphics system
shown is the stereoscopic representation (which is
guided (tracked) using the position detection sensor
system 130 - 140) of the respective three-dimensional
scene data 115. In this case, the perspective of the
25 scene representation depends on the observer's vantage
point and on the head position (HP) and viewing
direction (VD). To this end, the head position (HP) is
continuously measured using a three-dimensional
position measurement system (not illustrated here) and
30 the geometry of the view volumes for both eyes is
adapted according to these position values. This
position measurement system comprises a similar sensor
system to said position detection system 130 - 140 and
may be integrated in the latter, if appropriate. A
35 separate image from the respective perspective is
calculated for each eye. The difference (disparity)
gives rise to the stereoscopic perception of depth.

In the present case, an interaction by a user is understood as meaning any action by the user, preferably using said interaction unit 125. Included in this case are the movement of the interaction unit 125 on a spatial trajectory shown in figures 2a - 2c and the operation of one or more pushbuttons 195 which are arranged on the interaction unit 125. Acoustic actions by the user, for example a voice input, or an action determined by gestures may additionally be included.

Figures 2a - 2c then illustrate typical spatial trajectories 200 which result when the above-described interaction unit 125 is moved. It should be emphasized that, for the purposes of simplification, figures 2a - 2c show only a two-dimensional section of the formation which is actually three-dimensional. In this case, spherical shells which are to be represented have been degenerated to lines, for example. The respective direction of movement along the course of the trajectory is indicated by arrows 203. It shall be assumed that the user 105 (not shown in this illustration) respectively uses the pushbutton 195, for example, at the point 205 and at the points 205', 205'', 205''' on the trajectory, to signal to the VR graphics system (fig. 1) that an initial spatial point (ISP) 205 with an associated reference coordinate system 210 is to be determined. The spatial coordinates which correspond to the ISP and, as described above, are determined using the position detection sensor system 130 - 140 are transmitted to the digital computer 150 by radio in this case. From this time on, the further points on the trajectory 200 are calculated in relation to this ISP, virtually in new relative coordinates.

At the same time as the reference coordinate system 210 is determined, two shells which are arranged around the ISP 205 are calculated, to be precise an inner shell

215 having corresponding shell segments 217 and a continuous (i.e. not subdivided into such shell segments) outer shell 220. It should be emphasized that, in the technical sense, the shells shown represent only auxiliary means when calculating said threshold values and when calculating or detecting when these threshold values have been exceeded by the spatial trajectory of the interaction unit 125 and these shells therefore do not visually appear in the scene. The inner shell 215 defines the first threshold value mentioned at the outset, whereas the outer shell represents said second threshold value.

When penetrated by the trajectory 200, said shell segments 217 of the inner shell 215 are used to automatically trigger actions, preferably in a menu system of a user interface that is visualized in the present scene, to be precise actions such as opening a new menu item or selecting a function or a function mode from a multiplicity of functions or function modes offered. All known and conceivable manifestations, for example sphere-based or ellipsoid-based menus, cube-based or cuboid-based menus or flat transparent text menus, are suitable, in principle, as the menu system. The precise method of operation of such menu systems for selecting function modes or the like is described in detail in the two documents mentioned at the outset and these documents are therefore referred to in full in this respect in the present context.

The course of the trajectory shown in fig. 2a corresponds to a scenario in which the user operates the pushbutton 195 while moving the interaction unit 125 in order to select a menu. In this case, operation of the pushbutton also causes a menu system to be visually inserted into the scene 115. The precise position of this insertion on the projection screen 100 is determined on the basis of the viewing direction

(VD) 190 and/or the head position (HP) of the user 105. In this case, provision may be made for the viewing direction (VD) and/or the head position (HP) to be detected continuously or occasionally and for the

5 precise position at which the menu system or the function selection system is inserted to be determined on the basis of the viewing direction (VD) detected and/or the head position (HP) detected.

10 For reasons of symmetry (spherical symmetry of the above-described shells), the present exemplary embodiment is likewise preferably a spherical symmetrical menu system, for example a spherical menu. It goes without saying that the spherical shells shown

15 in figures 2a - 2c are only exemplary and may also be formed by cube-shaped, cuboidal or ellipsoidal shells. Cubic symmetrical shell shapes, for example, are thus suitable in menu systems which are likewise cubic symmetrical (cube-shaped, cuboidal or in the form of

20 text).

The trajectory 200 shown in fig. 2a penetrates the inner shell 215 for the first time in the region of a first spherical shell segment 218. This triggers a

25 first menu or function selection. The trajectory 200 then enters the inner region of the shell 215 again at the level of this segment 218 in order to penetrate said shell 215 again at the level of a second spherical shell segment 222 and thus trigger a further function

30 selection. The further course (indicated by dots) of the trajectory 200 is no longer important in the present case.

It goes without saying that, in the simplest

35 refinement, the threshold value areas shown in figures 2a - 2c may also be formed by scalar threshold values, for example in the case of a cubic reference coordinate system instead of the spherical coordinate system shown

here, only a single scalar threshold value having to be
determined in each of the three spatial directions.

Fig. 2b illustrates the course of a trajectory in
which, after the ISP 205 has been determined, the
trajectory 200 first of all penetrates the inner shell
215 in the region of a spherical shell segment 219, as
a result of which a function selection or the like is
again triggered. In contrast to fig. 2a, the trajectory
then also penetrates the outer shell, to be precise at
the point 225 shown. This penetration of the outer
shell gives rise to the automatic correction (already
mentioned) of the reference coordinate system 210, the
ISP 205 being shifted to said penetration point, i.e.
to the point 225 in the present case, in the present
exemplary embodiment.

In an alternative refinement, the ISP follows the
trajectory incrementally (i.e. in incremental steps or
virtually gradually), either the outer shell being
degenerated to a shell with a smaller diameter than the
inner shell or the ISP respectively following the
continuing trajectory incrementally as of said
penetration point 225. As already said, the outer shell
does not have any segmentation since it is not intended
to trigger any use-specific events but merely said
correction of the entire reference coordinate system
210.

Fig. 2c is finally intended to be used to illustrate
what happens when the interaction unit 125 is moved
over a relatively long distance, after an ISP 205 has
already been determined, for example owing to the fact
that the user is moving over a relatively long distance
in front of the projection screen 100 after a menu
system has already been activated. As follows from the
above description, repeatedly leaving the outer shell
220 gives rise to repeated correction (three times in

the present exemplary embodiment) of the ISP 205,
respectively resulting in ISPs 205', 205'' and 205''',
and of the reference coordinate system 210 associated
with said ISP, respectively resulting in reference
5   coordinate systems 210', 210'' and 210''' which have
been correspondingly shifted and are illustrated using
dashed lines in the present case.

It should be noted that, for the purpose of
10 generalization, the physical spatial trajectory shown
in figures 2a - 2c may be represented either by a pure
translational movement or a pure rotational movement of
the interaction unit 125 or else by a combination of
these two types of movement. In the case of such
15 rotational movements of the interaction unit in order
to trigger particular interactions with an above-
described menu system or in order to manipulate virtual
objects in the scene 115, provision may additionally be
made for the interaction to be triggered only when at
20 least one second interaction, in particular using the
control element, has been triggered. This
advantageously prevents even a slight rotation (which
may be undesirable) of the interaction unit 125
triggering an interaction. It is also possible for
25 rotations of the interaction unit 125 to be canceled
again without even having to trigger an interaction in
the VR graphics system.

Fig. 3 now shows an exemplary embodiment of an
30 inventive routine for evaluating the spatial course of
a trajectory which has been assumed as in figures 2a -
2c. After the start 300 of the routine, which is
preferably triggered by switching on the VR graphics
system or by, for instance, subsequently activating the
35 interaction unit 125, the routine is first of all in a
waiting loop in which a check is continuously or
occasionally carried out 305 in order to determine
whether the user has carried out an interaction in

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order to determine, if appropriate, an above-described
initial spatial point ISP 205 at the instantaneous
spatial position of the interaction unit. This
"initial" interaction is preferably effected using the
5 above-described pushbutton 195 but may also be effected
in the manner described at the outset by means of
voice, gestures or the like.

If such an initial interaction is determined, said
10 reference coordinate system 210 is first of all
determined in step 310, the coordinate origin being
formed by the ISP 205. In subsequent steps 315 and 320,
the reference points or reference area segments 217 of
said first threshold 215 and the second threshold area
15 220 are determined in the reference coordinate system
210.

Said steps are again followed by a loop in which the
current position of the interaction unit 125 is first
20 of all detected 325. A check is then carried out 330 in
order to determine whether the detected value of the
current position is outside said first threshold value
or the value of the present reference area segment 217.
If this condition 330 is not satisfied, the routine
25 jumps back to step 325 in order to detect a new current
position value of the interaction unit 125. However, if
the condition 330 is satisfied, the trajectory has
penetrated the first threshold area 215. In this case,
a check is also first of all carried out 335 in order
30 to determine which reference point or which reference
area segment in the reference coordinate system is
affected thereby. The corresponding function or menu
selection is then triggered 340 on the basis of the
result of the last check 335.

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In the special case of the triggered function being a
function that ends the entire routine, which is

additionally checked in step 342, the process jumps to
step 343 in which the routine is then ended.

In the case of the trajectory actually having
5   penetrated the first threshold area 215, a check is
also carried out 345 in order to determine whether the
trajectory has also already penetrated the second
threshold area 220. That is to say a check is also
carried out 345 in this case in order to determine
10 whether the magnitude of the value of the current
position of the interaction unit 125 in the present
reference coordinates exceeds the value of the second
threshold. If this condition is not satisfied, the
process jumps back to step 325 again and a new position
15 value of the interaction unit 125 is detected.
Otherwise, the reference coordinate system and its
origin 350 which coincides with the ISP 205 are
corrected and, if appropriate, incrementally shifted to
the current position of the trajectory of the
20 interaction unit 125.

It should finally be noted that the above-described
concept of the initial spatial point (ISP) also
includes, in principle, user interfaces in which the
25 interaction is effected using a pure rotation of the
interaction unit 125 or a combination of a pure
translation and a pure rotation. In the case of a
rotation, the ISP can be understood as meaning an
initial spatial angle $\varphi = 0°$ of an imaginary spherical
30 or cylindrical coordinate system. In this case, the two
threshold values described may be formed by discrete
angles, for example $\varphi = 90°$ and $\varphi = 180°$, said
coordinate system then being corrected, for example, by
the angle $\varphi = 180°$ when the threshold values are
35 exceeded by $\varphi = 180°$.